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The Use of Different Technological Methods for Teaching Basic Suturing Skills to Medical Students: A Literature Review

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ABSTRACT

Suturing skills are usually acquired by medical students through observation and then practice. There is a pressing need to develop more efficient teaching methods as students are often unprepared to perform suturing in clinical practice. This study therefore aims to investigate the benefits and limitations of different technological teaching methods and determine if technological methods are superior to conventional teaching. The search was conducted using ScienceDirect, PubMed and Scopus with different combinations of the key terms "suturing", "suture", "knot-tying", "suturing skill", "surgical skill", "teaching methods" and "medical students". Overall, 19 relevant articles were shortlisted, discussing the use of virtual reality, augmented reality, videos and programmes in teaching suturing skills. The use of instructional videos is a good alternative to the traditional lab-based method while video self-reflection was found to be an effective enhancement. Integration of these methods could be a valuable addition to the current curriculum.

Keywords: *Suturing, Surgery, Medical students, Education, Teaching method*

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INTRODUCTION

Suturing skills in medical school have conventionally been taught in a lab-based environment with hands-on practice for students to hone their skills (1). Skills are usually first acquired by medical students through observation and then performing surgical procedures themselves (1). Having the ability to suture is a crucial skill for many doctors and hence, medical students need to be taught well during medical school.

However, students are often unprepared to perform suturing in clinical practice, resulting in a pressing need to develop more efficient teaching methods (2). With the advancements in technology, it is perhaps time to consider better methods of teaching suturing skills to medical students, such that they remain proficient even after graduation. The current climate of the COVID-19 pandemic may also call for methods allowing remote teaching (3).

Currently, many medical institutions are incorporating technology into their education curriculum. Some examples include virtual reality (VR), augmented reality (AR), video-based instruction and computer-based learning.

To date, there have been no literature reviews regarding the use of various technological methods to teach suturing skills to medical students. This study aims to investigate the benefits and limitations of using different types of technology for teaching and determine if technological methods are superior to conventional teaching.

METHOD

Search Strategy

The search was conducted using scientific databases: ScienceDirect, PubMed and Scopus. Different combinations of the key terms "suturing", "suture", "knot-tying", "suturing skill", "surgical skill", "teaching methods" and "medical students" were used to find eligible studies.

Inclusion Criteria

Language of publication was restricted to English and studies selected were all original articles. Studies investigating different technological teaching methods for basic suturing skills were shortlisted for review. With the aim of consolidating and reviewing alternative suturing instructional methods in medical schools, we only included studies where medical school students are participants and the teaching methods rely on technology.

Exclusion Criteria

We excluded articles which have an exclusive focus on specific suturing techniques such as knot tying and laparoscopic suturing. Articles discussing non-technological or traditional teaching methods for surgeons or residents were also excluded from this review. Review articles, news items and conference abstracts were not included in the search.

Search Selection

Relevant studies were first identified by reviewing the titles and abstracts, according to our inclusion and exclusion criteria. The shortlisted articles were then ascertained for their relevance by reviewing the full texts. We also combed through the citation lists of shortlisted articles to further identify relevant studies for discussion.

Data Extraction

Data illustrating the effectiveness, benefits and limitations of the different technological methods for teaching suturing was extracted and compiled into a table (refer Table 1). Specific information extracted includes the sample size, duration of intervention, method of intervention, method of assessment and the benefits and limitations of the teaching method.

Table 1: Summary of the 19 studies investigating the different technological methods for teaching suturing skills in medical students (4–24)

Authors, year, country	Sample size	Duration	Method of intervention	Method of assessment	Results	
					Benefits of intervention	Limitations of intervention
O'Toole et al., 1999, United States	12	One-off	Each participant performed a designed VR task for 15 consecutive times. There were three different test conditions: using the dominant hand, using the non-dominant hand and using the 3D needle guide.	Seven parameters were used to assess suturing skills: needle placement accuracy, surface tissue damage, tissue damage after puncture, peak force, angular error in following the curve of the needle during suturing, time to complete the task, and a total score based on the average of the above parameters. Participants' scores in each parameter and an overall error score were displayed to them at the end of each trial.	Improved technical performance was recorded in six out of seven parameters: excess time, accuracy error, surface damage, peak force, tissue damage, and overall error score.	There was no statistically significant improvement for one of the parameters, excess tool motion. Students may have demonstrated improvement from increased familiarity with the simulator.
Amirian et al., 2014, United States	19	One-off	Participants were split into two groups, the VR training group or dry lab training group, with a baseline suturing performance evaluation and a final evaluation done before and after the training sessions, respectively.	A unique evaluation method was adapted from the intracorporeal knot evaluation method by Derossis et al. Participants in the VR training group also participated in a survey to rate the face and content validity of the programme after the training was completed.	Scores for suturing timing improved for 9/9 participants in the dry lab training group and for 8/10 participants in the VR training group. An average improvement of 0.63 and 1.33 mm in accuracy was recorded in the dry lab and VR groups, respectively. The participants acknowledged the realism of clutching, depth/spatial relationship, needle driving, and visual appearance of the simulator and found the clutching, depth/spatial relationship, needle driving, tissue behaviour, and visual appearance of the simulator useful for training.	The participants did not agree with the realism of the simulator, with a median survey score of 2.6 out of 5.

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Table 1 (*continued*)

Authors, year, country	Sample size	Duration	Method of intervention	Method of assessment	Results	
					Benefits of intervention	Limitations of intervention
Lemke et al., 2019, Canada	44	1.5 hours per session	Students were randomised to the faculty-led, peer tutor-led and holography-augmented groups. The faculty-led and peer tutor-led groups received direct guidance and feedback from faculty surgeons and peer tutors, respectively. The holography-augmented group utilised a training platform, suture tutor, which displays holographic and voice-controlled instructional videos. Participants in this group received real-time guidance and feedback by comparing their own hand motions and sutures against those shown by the suture tutor.	Hand motion analysis was used as an objective evaluation method to assess participants' suturing and knot tying skills.	All participants trained using the holography-augmented platform were able to achieve the targeted proficiency.	There were no statistically significant differences in suturing performance between the holography-augmented training group and the traditional groups. The holography-augmented method was also significantly more expensive than the peer- and faculty-led groups. About 78% of the participants preferred the faculty-led teaching, 22% preferred the peer tutor-led teaching while 0% preferred the holography-augmented teaching. Participants feedbacked that as the holography-augmented platform lacked personalised feedback, they were unsure of how to improve their skills to achieve proficiency.
Lia et al., 2018, Canada	32	One-off	Participants were split into two groups, the HoloLens group or the control group. The HoloLens group utilised the suture tutor where the participants can pause, repeat, slow and skip instructional videos using voice control. The suture tutor training platform keeps a record of the number of times each video was viewed and the time taken to learn each step. The control group was trained using the same instructional videos on a laptop instead. A record of the number of times each video was viewed and the time taken to learn each step was also noted down manually using a stopwatch.	A baseline test was conducted, where participants videoed their attempt. After practicing with their assigned methods for seven minutes, participants were videoed again performing the same task within five minutes but with no guidance. This video was used as their final test. After the session, participants in the HoloLens group also completed a survey on the usability and realism of the training.	Participants feedbacked that the Hololens is usable and realistic. Participants in the HoloLens group utilised the instructional videos more compared to the control group.	There were no statistically significant differences in suturing performance test scores between the HoloLens and the control group and both groups had similar rates of completing the task.

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Table 1 (*continued*)

Authors, year, country	Sample size	Duration	Method of intervention	Method of assessment	Results	
					Benefits of intervention	Limitations of intervention
Routt et al., 2015, United States	–	Three months	Retention of suturing skills was investigated with respect to the teaching methods used. Students were split into two groups with one being taught on day one through an instructional video and tested for proficiency on day 30 and the other being taught on day one and tested for proficiency on days 10, 20 and 30.	Students were evaluated using the Simple Suture Scoring Rubric and the Global Rating Scoring Sheet.	Retention of suturing skills in medical students was found to be much better in the group with multiple sessions of video teaching and feedback by experts than in the group with a single session of video instruction and feedback, with the same total teaching time. All students in the group with no repeated teaching sessions did not pass the post-intervention test at all, at the end of 30 days, while 91% of the experimental group with multiple spread-out teaching interventions in the 30 days had passed.	–
Xeroulis et al., 2007, Canada	60	One month	Participants' suturing and instrument knot-tying skills were assessed as baseline evaluation after watching an instructional video. Students were split into four intervention groups: no additional intervention, self-study with computer-based video instruction, live feedback from experts and summary feedback from experts.	For the post-test, the last practice trial was used. After a month, a retention test was carried out using the same skills of suturing and instrument knot-tying. Evaluation was done using expert- and computer-based assessments with global rating scores and hand motion analysis.	Computer-based video intervention and summary feedback methods proved to be the most effective at retaining knowledge and skill of suturing and knot-tying, as compared to control which received no additional intervention.	–
Nousiainen et al., 2008, Canada	24	Four weeks	All participants initially viewed an instructional video on instrument knot-tying. Students were split into three groups: self-directed learning with video, self-directed learning with interactive video and the combination of self-directed learning with interactive video with expert instruction.	Performance in the pre-, post- and retention tests was assessed using computer- and expert-based methods.	Motion efficiency improved from pre-test to post-test. There was minimal forgetting of the skill over the one-month retention period.	The combination of video and expert instruction did not improve the development or retention of the surgical skills of suturing and knot-tying in medical students compared to training with video material alone.

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Table 1 (*continued*)

Authors, year, country	Sample size	Duration	Method of intervention	Method of assessment	Results	
					Benefits of intervention	Limitations of intervention
Rogers et al., 1998, United States	82	One hour (per educational session)	Students were split into two groups: Lecture and feedback seminar, where a series of photographic slides were used to demonstrate tying a pair of two-handed square knots. Computer assisted learning, where one computer per person was used. Videotape with perspectives similar to the slides was made. Tasks could be viewed in real time or in slow motion. Text was shown in each of these steps that was identical to the lecture group's slides.	Students were videotaped, and these tapes were independently and blindly reviewed by three surgical faculty members who recorded whether they thought the knot was square. The surgeons evaluated the quality of the knot tying using a rating scale. The number generated using the rating scale was termed the performance score, with a maximum score of 24. The time for the task was also recorded for each of the students.	–	The lack of feedback was the most significant negative feature of computer assisted learning. Students who underwent computer assisted learning had significantly poorer proficiency in surgical skill compared to students in the lecture feedback seminar group.
Kumins et al., 2020, United States	221	Three and a half years	Seven videos for knot tying and five videos for suturing were used in the teaching. Homemade practice suturing boards, sutures and relevant instruments were provided for students to take home.	Their product quality score and assessment of technique were measured using standard global rating scale (GRS) were <0.4 for six measured skills (scale 0–5).	It was an effective learning tool according to students. Every student who completed the course demonstrated a significant increase in the six assessed surgical and suturing techniques as measured by the GRS and product quality score (PQS). Completing the course increased students' basic knowledge of identifying instruments and proper surgical technique. There were flexible opportunities for trainees to learn and practice on their own in a self-paced manner.	It is unclear whether students can retain these skills as scores were subjective, not objective. It does not reflect on performance in real life clinical settings as well. The videos were released sequentially over time, but do not know if that helped or not.

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Table 1 (*continued*)

Authors, year, country	Sample size	Duration	Method of intervention	Method of assessment	Results	
					Benefits of intervention	**Limitations of intervention**
Shippey et al., 2011, United States	58	Four months	All were shown an instructional video before the pre-test. The first group could keep viewing that same video, the second group had an instructor who provided feedback, and the third group did independent practice. Pre-test was administered first, followed by practice, then post-test was carried out after 30 minutes. Another retention test was carried out after one week.	All the tests were videoed and scored using an 8-item rating scale, the subcuticular suturing assessment form. Likert scale, global and task specific subscales, each composed of four items were also used.	Retention of knowledge was most significant in the video group. This method was a better use of time as students were able to focus on certain parts of the videos addressing their uncertainty, allowing more time for hands-on practice. Videos allowed for comparison of work with the video for visual feedback. Videos were both instructional for students, and acted as a visual benchmark.	–
Tejos et al., 2020, Chile	130	Four weeks	Students were split into three groups: Video learning group – Students trained at home by imitating the video contents on simple suture techniques without direct feedback from anyone. Peer feedback group – Each student imitated the video contents while a classmate observed the procedure and performed feedback by applying objective structured assessment of technical skills (OSATS) and specific rating scales (SRS). Expert feedback group – There were six in-person suturing training sessions held with experienced teachers for students, and experts provided direct feedback to five students maximum.	The video recordings of pre-assessment were made immediately after the introductory class and before the randomisation. The post-assessment video recordings were made immediately after the last training session. The video recordings of students were randomly analysed by two blinded experts who did not participate in any other training or educational activity. GRS including OSATS and SRS were used to evaluate the students.	The encouraging results of the peer feedback methodology place it as an alternative to handling the emerging demands in medical education.	Video-guided learning methodology without any kind of feedback is not enough for the development of an optimised teaching programme in suturing skills compared to expert or peer feedback.

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Table 1 (*continued*)

Authors, year, country	Sample size	Duration	Method of intervention	Method of assessment	Results	
					Benefits of intervention	Limitations of intervention
Chien et al., 2015, United States	36	One to three months	Students were split into video-based learning, and lecture workshop learning groups. The lecture workshop structure was as such: 20 minutes of lecture, then 100 minutes of practice and feedback.	Two faculty physicians provided mentorship, project oversight and assessment of student suturing performance using the 22-point suture task checklist.	Students who participated in video-based learning (VBL) had no significant difference in suturing scores at one and three months compared to traditional live workshop learning (LWL) suggesting that VBL may be as effective as live workshop training. The implementation of accessible VBL into medical students' pre-clinical education may be an effective way to teach students procedural skills while saving time, space and resources.	Some limitations to this VBL mode of learning include limited interaction with residents and physicians and lack of instructor feedback. Limitations to this study including no pre-intervention evaluation suturing skills, small sample size, limited quality of overhead camera used to capture suturing techniques and ties.
Gammill et al., 2020, United States	148	Two years	Students were provided online video resources and suturing materials for independent practice, followed by hands-on instruction starting on their own gross-laboratory cadavers, during divided sessions throughout the M1 and M2 years covering key suturing skills. Each session, students focus on practicing the next set of skills on their list. A 2-hour refresher session is provided immediately prior to starting M3 clinical clerkships.	Participants filled in evaluation surveys before and after the first training session to assess pre-intervention suturing experience, comfort level suturing skills, and impressions of overall course design.	Students were exposed to suturing much earlier than otherwise expected during their medical education. The programme appears to be a worthwhile use of both faculty resources and students' time due to the positive responses and improved comfort level with basic suturing skills.	–
Nesbitt et al., 2015, United Kingdom	32	One-off	Students were split into three groups. One group got a generic lecture, one watched an unedited video of their suturing performance and were given feedback, and the one watched a video of their own performance, an edited video of an expert performing the suturing exercise, with additional expert commentary, and a video of an expert delivering "hints and tips".	Scoring of students was done by two experts who observed their performance, and two blinded experts who used a modified form of the objective structured assessment of technical skill scoring tool to grade them.	There was a statistically significant improvement in actual score in all groups, but specifically in the video and feedback groups.	–

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Table 1 (*continued*)

Authors, year, country	Sample size	Duration	Method of intervention	Method of assessment	Results	
					Benefits of intervention	**Limitations of intervention**
Alameddine et al., 2018, United States	16	–	Participants were split into two groups: Intervention group – watched their suturing video with a surgery faculty member and were coached on their performance. Control – no coaching received between suturing tasks.	Global Operative Assessment of Laparoscopic Skills developed by Vassiliou et al., seven modified to make it more appropriate for our suture task. All the tasks were recorded, and assessed by faculty members.	The intervention group demonstrated greater subjective, average improvements in all domains. Intervention group demonstrated greater improvements in bimanual dexterity. Control group demonstrated greater average improvements in the efficiency and tissue handling domains of suturing skill. Intervention group would recommend peers. Easily obtainable equipment and cost-effective. Students are able to gain insight into their own clinical abilities from a different perspective.	Disparity between student self-assessments and faculty evaluations as self-assessments are based on recall while faculty evaluations are based on video review. It gives some a false sense of improvement after coaching. Intervention group may have had better performance given more time to practice. Recently coached students may be hampered by the desire to try newly coached skills for the first time, hindering their speed and smooth movement of instruments.
Wang et al., 2020, Canada	31 students 6 residents	Two weeks	Students were split into two groups: Self-regulated group: 1-hour practice while supervised by faculty experts, with feedback. Modified OSATS evaluation tools and instructional videos were given for self-practice. Reflection group: Provided with a reflective guide, a copy of their pretest video and the instructional videos, with no feedback. Participants could view the pre-test video and compare it to the instructional video as many times as they liked, then reflect on this experience.	Modified OSATS tool evaluated on three tasks. Blinded evaluators used global rating scale to rate their competence.	Participants in the reflection group achieved competency with less resources and without the need of an external expert – but they do not feel confident about their skills.	No significant improvements observed in both groups. Students' self-assessment skills need to be honed, with addition of specific criteria to minimise inaccuracies and differences in standards in assessment. Students do not feel confident without expert feedback despite improvement.

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Authors, year, country	Sample size	Duration	Method of intervention	Method of assessment	Results	
					Benefits of intervention	Limitations of intervention
Hu et al., 2013, United States	16 students, 7 surgical interns	Four weeks	Students were video-recorded while performing five suturing and knot tying tasks using an objective structured assessment of technical skills metrics.	Within four weeks of training, a video self-assessment was conducted and students were then assessed by a senior surgery instructor. Post-course survey asked participants to rate the value of the video self-assessment process, and to indicate which basic techniques required additional practice.	Participants on average rated the experience to be "highly valuable". This method can guide independent practice through self and expert-assessment without student becoming overconfident.	Judgement of technical skills is operator-dependent, and there may be personal bias when assessing the students.
Sato et al., 2019, United Kingdom	24	One-off	Suturing skills training workshop with 24 pre-clinical medical students. The tutor sutured while wearing the smart glasses and then students used the smart glasses to video-record their performance. There was reflection and feedback of performance, both as individual students and as a peer group.	A semi-structured questionnaire was anonymously completed at the end of the workshop and data was analysed by thematic analysis.	Point-of-view video enhanced reflection and feedback. It also allowed students to identify specific aspects of their performance they otherwise would not have noticed.	Some wearers complained of minor discomfort due to bulkiness of glasses. The smart glasses also caused some anxiety in students. The high cost of the smart glasses was a concern as well.
Peden et al., 2016, United Kingdom	14	One-off	Students were split into three groups: Conventional teaching, head mounted display assisted teaching, head mounted display self-learning (google glasses)	Students undertook a practical assessment after the interventions. Their suturing was videoed and graded by masked assessors using a 10-point surgical skill score.	Head mounted teaching was more enjoyable than conventional teaching. Head mounted display could be more useful in settings with higher student to instructor ratios.	Costly method of teaching, as smart glasses cost $1,500. Head mounted display method of learning was not found to be better than conventional methods, and Google Glass has a small display with poor quality videos.

RESULTS AND DISCUSSION

Overall, 19 relevant articles were shortlisted. The shortlisted articles can be categorised into:

a. Articles discussing the use of and AR, technology in teaching suturing skills.

b. Articles discussing the use of instructional videos or programmes in teaching suturing skills.

c. Articles discussing the use of video feedback in teaching suturing skills.

d. Articles discussing the use of point-of-view video in teaching suturing skills.

Effectiveness of VR and AR Technology as Teaching Methods for Suturing Skills

A total of 4 out of the 19 articles discussed the various uses of VR and AR as innovative methods for teaching basic suturing skills. The four articles covered two different designs of VR surgical simulators and a holography-augmented training platform using voice commands and statistical analysis.

Improvement in suturing performance

In O'Toole et al.'s study, the medical students showed significant improvement in six out of the seven parameters used to quantify suturing skills after the training session, although it is debatable whether the improvement was due to an actual refinement in suturing skills or due to increased familiarity with the 3D needle simulator (4). For Amirian et al.'s version of the VR surgical simulator, participants also showed statistically significant improvements in suturing skills, but it is notable that there were no statistically significant differences between participants trained using the surgical simulator and participants who underwent dry lab practices instead (5). Similar results were shown in Lemke et al. and Lia et al.'s studies, where participants showed an increase in proficiency level with no statistically significant differences from the control groups (7–8).

Objective measure to record data and track progress

The VR simulators in O'Toole et al. and Amirian et al.'s study had an important advantage in being objective measures of surgical suturing skills. They were able to provide the users with detailed information regarding the simulated tissues, surgical tools and motions of the user using carefully programmed VR technology. The VR simulators were also able to record performance data during the training session and provide these data as a form of feedback to users, allowing users to review their performance and track their technical progress (4–5).

More realistic simulation and practice opportunities

VR and AR offer more realistic simulation as compared to the use of live animals, inert materials and cadavers. The realism of the simulator was justified in O'Toole et al.'s study by a pre-test showing significantly better surgical performance by qualified surgeons than medical students when using the surgical simulator (4). The authors reasoned that the ability of the simulator to differentiate between the skills of surgeons and medical students showed its success in being a realistic simulator for practice and measurement of skills (4). In Amirian et al.'s study, a post-training survey was conducted and participants confirmed the realism of the surgical tool simulators but rejected the validity of the simulator's tissue behaviour (5). Participants in Lia et al.'s study also confirmed the enhanced realism of the HoloLens (8).

Participants' preferences

In Amirian et al.'s study, participants of a post-training survey found the surgical simulators useful in training suturing skills

(5). However, in Lemke et al.'s study, the lack of personalised feedback was amongst the reasons for the holography-augmented training programme being the least preferred, compared to traditional methods of faculty- and peer-led discussions (7). There was also feedback given by the participants on the discomfort of wearing headsets while undergoing training (7). Participants in Lia et al.'s study found the HoloLens training useful (8).

Other benefits

An obvious advantage of these technologically advanced training methods would be their availability at any time of the day, where students can obtain realistic training without being restricted by operating theatre schedules. They can also minimise the risks to patients and lower cost in the long run, other than Lemke et al.'s study which found out that the incremental costs of the holography-augmented training programme were actually greater than traditional methods (4–8).

Limitations of studies

Small sample size was a common limitation across O'Toole et al. and Amirian et al.'s studies, where data collected may not be able to represent the whole medical student cohort (4–5). Only one training session was conducted in O'Toole et al.'s study, and hence there are concerns as to whether the improvements recorded were transient and not representative. The improvements shown may also be due to increasing familiarity with the surgical simulators instead of actual improvements in surgical skills (4). Amirian et al.'s study faced possible response bias as participants who volunteered for the research were likely to be more surgically-inclined (5). For Lemke et al.'s study, it was difficult to obtain an objective measure of the cost savings of the different intervention methods used as many factors were difficult to quantify, including faculty time cost and the ability of peer tutors to teach more participants or train more peer tutors at the same time (7).

Effectiveness of Instructional Videos or Programmes for Teaching Suturing Skills

In total, nine articles discussed the use of video instruction as a teaching method for suturing skills.

Overview of relevant articles

In the studies, video instruction was often used together, or compared with other teaching methods, such as reinforcement of learning (9), computer-based video instruction programmed training (10–13), learning with an expert instructor's feedback (10–11, 14–16) or peer feedback (15), and traditional lecture or seminar learning (12, 16).

Improvement in suturing performance

Some studies discussed the effectiveness of video instruction, or video instruction with other methods for teaching suturing skills, by comparing pre- and post- intervention test scores.

In Kumins et al.'s study, students took part in a self-directed computer-based video training for their surgical skills. They demonstrated a significant increase in the six assessed surgical and suturing techniques (13). Completing the course increased students' basic knowledge of identifying instruments and proper surgical technique (13). However, video-guided learning in Tejos et al.'s study was found to correlate with significantly inferior post-assessment results, as compared to the expert and peer feedback group (15). This same sentiment was found in Rogers et al.'s study (12). Students who underwent computer-assisted learning had significantly lower quality of suturing performance as compared to the group that underwent a lecture feedback seminar (12).

Xeroulis et al. and Shippey et al.'s studies both found that overall, students' suturing performance improved following a computer-based video instruction (10) and video instruction intervention (14). In Nousiainen et al.'s study there was found to be no significant differences between the use of video instruction, interactive video instruction, and interactive video instruction with expert feedback on the learning and retention of suturing and knot-tying skills in medical students, although all groups showed significant improvements between the pre- and post-tests (11).

Overall, the use of video instruction or computer-assisted learning programmes was seen to be a teaching method with much potential for skill-training in medical students. The use of instructional videos as a potentially efficient and effective teaching method could help to save time and resources in times of increasing demands for medical education (10, 12–17). This is very relevant, especially in times of a pandemic such as the 2019 novel coronavirus outbreak, when remote learning is being carried out and would likely require the use of self-directed learning and video instruction to teach practical skills like suturing to medical students.

Participants' preference

In Kumins et al.'s study, students found the videos to be an effective learning tool (13). However, the medical students in Tejos et al.'s study did not find the video-guided learning methodology without any kind of feedback to be effective (15). Similarly, in Rogers et al.'s study, the students felt that the lack of feedback in computer-assisted learning was not helpful for the students at all (12). Gammill et al.'s study only collected feedback from students, without pre- and post- intervention tests. Students expressed their improved comfort in basic suturing skills: they became more familiar with the correct positioning of instruments and carrying out simple interrupted sutures and instrument ties (17).

Retention of knowledge

Some studies discussed the impact of video instruction, or video instruction combined with other methods on the teaching and retention of suturing skills.

Routt et al.'s study found that reinforced learning through multiple teaching sessions using video instruction was more effective for the retention of suturing skills in students than singular teaching sessions (9). In Xeroulis et al.'s study, students' retention of knowledge one month after the intervention was significant only for the computer-based video instruction group and summary feedback group (10). Similarly, significant retention of knowledge one week after the intervention was only seen in the students who had undergone instructional video teaching intervention (14). All groups in Nousiainen et al.'s study, using video instruction, interactive video instruction and that with expert feedback, showed significant improvements between pre-tests and retention-tests (11). Addition of expert instruction did not cause significant improvements in retention of skills, and non-interactive video was found to be as effective as interactive-video-based instruction (11). A similar result was also seen in Chien et al.'s study (16). Students who watched a video recording of a training workshop were found to have no significant difference in suturing retention scores at one month and three months, when compared to traditional live workshop learning. Chien et al.'s study thus suggested that video-based learning and live workshop training methods were of similar efficacy in teaching and retaining suturing skills of students (16).

Benefits of using instructional videos

The primary advantage of instructional videos over conventional teaching methods is time effectiveness (10, 12–17). Additionally, they reduce the need for faculty resources (14), a physician instructor (9), and a teaching venue

(13, 16). While conventional teaching is resource intensive and can only be conducted at fixed timings, instructional videos can be easily disseminated, studied by students at their own discretion and be reused for future batches.

Most studies agree that instructional videos are not inferior to conventional methods, and actually led to a higher retention of knowledge (9, 14). A possible explanation is that students can constantly refer to the video and focus on specific parts that they are not confident in. Additionally, they can constantly replay the instructions given, and learn by repetition. In addition, given the COVID-19 pandemic, there is a shift towards remote, self-directed learning (13), giving instructional videos a conferred advantage.

Limitations of using instructional videos

However, there are certain limitations to the use of instructional videos for teaching suturing skills. Routt et al.'s study showed that video-based learning needed students to remain motivated to learn to be successful, since spaced repetition, at 10 repetitions every 10 days for a month, was needed for a student to become competent at their knowledge (9). However, Routt et al. did not compare their results against a group that underwent conventional teaching methods (9), hence it is not clear whether conventional teaching also requires spaced repetition to be effective.

Some studies showed that video-based learning is inferior to conventional methods with expert or peer feedback as it does not contribute to the development of an optimised teaching programme (15). These results are not representative of students' performance in actual clinical practice (13) as with all simulations.

Effectiveness of Using Feedback from Reviewing Videos in Improving Suturing Skills

In total, five articles discussed the use of video feedback in improving suturing skills of medical students.

Overall, all intervention groups in Nesbitt et al.'s study demonstrated improvements in their overall procedure score, with the highest improvement in the unsupervised video feedback group, followed by the individualised video feedback group and subsequently the generic feedback group (18). There were slightly different results of the students' skills when they were assessed by faculty in Alameddine's study (19). The video-review group which received coaching manifested greater average improvement in bimanual dexterity, while the control group demonstrated better improvement in overall efficiency and tissue handling (19). However, it was hypothesised that the students who received coaching might have performed better if they were given more practice time. Of the group that was coached, most agreed that it was a beneficial experience for them and felt that the experience improved their technical skills. All said that they would recommend the coaching sessions to their peers. In Wang et al.'s study, the reflection group did better in one task while the self-regulated group did better in two other tasks (21). Hu et al.'s study revealed that while participants seemed to give themselves higher self-assessment scores than what experts scored them, most of them rated the self-assessment experience to be "highly valuable" (22). In Sato et al.'s article (23), the students stated that point-of-view recording allowed them to review their performance repeatedly and hence know what to seek feedback on from their tutors and peers, which benefited their learning.

Overall, it seems that video feedback could be a valuable tool for teaching suturing skills, with the efficacy of real-time coaching and feedback being promising.

Benefits of using feedback from reviewing videos

The benefits of this method include obtainability and cost-effectiveness (22), which makes them self-sustainable. However, ideally, there should also be external feedback along with it, in the form of either coaches (19) or "expert" video recordings (18, 21). Video recordings also allow students to review their performance repeatedly and seek out different peers and tutors for feedback (23).

Limitations of using feedback from reviewing videos

One limitation would be how the efficacy may be dependent on the motivation of each student (19). The onus of reviewing their own performance and evaluating points of improvement is entirely up to the student. Reviewing videos may hence be ineffective in students uninterested in picking up suturing skills.

Effectiveness of the Use of Smart Glasses in Teaching Suturing Skills

Two articles discussed the use of point-of-view video using smart glasses in educating medical students on suturing techniques.

In Sato et al.'s study, the tutor wore smart glasses while they demonstrated the suturing techniques to students through a live stream, from the surgeon's point of view (23). Afterwards, students used the smart glasses to record their performances from their own point of views, followed by a feedback session evaluating their performances (23). The use of smart glasses during the tutor demonstration was not seen to be very helpful as students preferred to look at the live demonstration instead of the streamed video (23).

In the other study done by Peden et al., similar use of head-mounted display eyeglasses was investigated to teach suturing skills (24). The students were split into three groups and watched instructional suturing videos from the surgeon's point-of-view to learn suturing skills. One group of students had access to tutors as they viewed the videos in their headsets, one group went through conventional teaching without the glasses, while the last group underwent self-directed learning with the smart glasses. Students' suturing abilities after the teaching sessions were about the same in all groups (24). The results of this study, where students found the use of smart glasses enjoyable, were different from that of Sato et al.'s study, where some students had mild discomfort and anxiety using the smart glasses (23).

Benefits of using point-of-view smart glasses

The students found the recorded, point-of-view videos of themselves to be very useful in reflecting on their suturing techniques. These videos provided perceptive angles to see the mistakes they would have otherwise not have seen from a normal video. Students also found the use of smart glasses more enjoyable as compared to conventional teaching in Peden et al.'s study (24).

Limitations of using smart glasses

The common limitations of this method are the high costs, and the limited resolution and image-recording quality of the smart glasses (23–24), although the quality of images would likely be improved with technological advances. Short battery life of the glasses and user fatigue were two other limitations reported in Peden et al.'s study (24). Overall, the use of the smart glasses to provide point-of-view feedback and teaching for suturing techniques seems to have high potential, compared to traditional video-recording methods.

STRENGTHS AND LIMITATIONS

This review has several limitations, mostly due to differing study methodologies and scoring systems, which makes it difficult to control for selection bias. Furthermore, all but one of the studies were conducted in Western countries, hence, this data may not be applicable worldwide. We had also restricted our literature search to only include studies in English, which could have resulted in missing potentially relevant studies.

COMPARISON WITH EXISTING LITERATURE

While Cook et al.'s study (25) compared the uses of technological simulation against other instructional methods, this review aims to provide a comprehensive summary of the technological teaching methods available for basic suturing skills and make a comparison between the different technological interventions. In terms of outcome, this review serves to summarise and analyse the effectiveness of different technological intervention methods on learning suturing techniques. This is a more specific goal than Cook et al.'s review (25) which compared the effectiveness of different interventions as broad-based instructional methods.

IMPLICATIONS FOR FUTURE RESEARCH

This review has consolidated the effectiveness of alternative ways of teaching suturing skills to medical students, other than the traditional lab-based or lecture methods. Future studies can investigate the effectiveness of different methods of teaching for suturing techniques in particular specialties, such as in orthopaedic surgery or laparoscopic surgery. Teaching methods involving combinations of several types of technology is also another area which can be investigated that could give insight on the best combinations of teaching methods to use in medical school curricula.

CONCLUSION

Suturing is a fundamental surgical skill that all medical students should be familiar with before entering their clinical years. Other than the traditional lab-based method where students have hands-on experience under the supervision of experts, following the advancement of technology, many new methods have cropped up to reduce cost and manpower, as well as improve the learning of the students. In particular, the use of instructional videos is a good alternative to the traditional lab-based method as it allows students to review the videos repeatedly. The video self-reflection on the other hand is a good enhancement to the traditional method, allowing the student to reflect on their performance and come up with areas of improvement. The integration of these alternative methods can be a valuable and suitable addition to the current suturing curriculum.

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